Dark Matter Working Group Discussion

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Future of Very High Energy Gamma-Ray Astronomy
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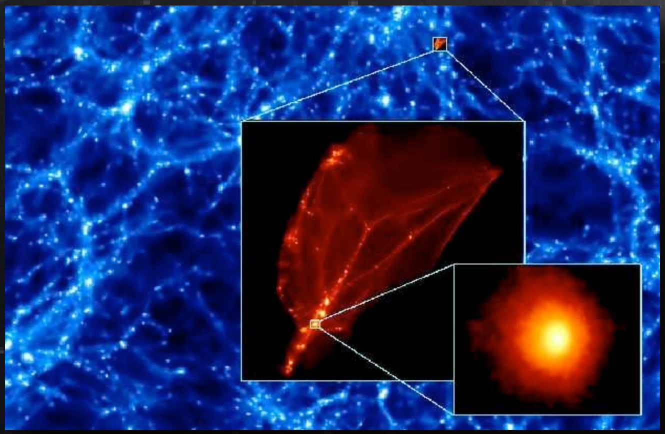
Key Points

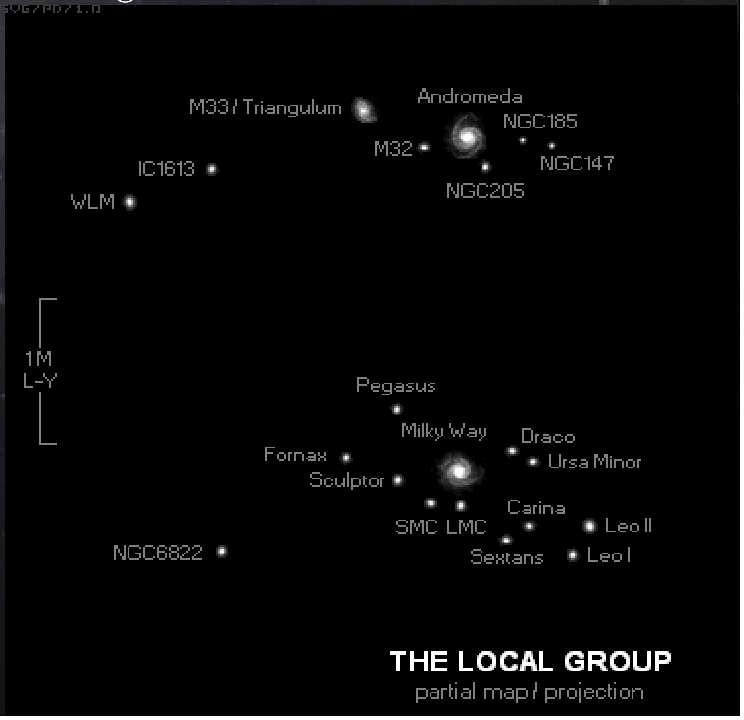
- Why Dark Matter?
  - To hold galaxies and galaxy clusters together, acoustic peaks in CMB and LSS, spatial segregation of gravitational lensing matter and X-ray emitting gas in clusters.
- Why look in the very-high-energy gamma-ray channel?
  - Weakly interacting particles escape Boltzmann suppression in the early universe. A conserved quantum number ⇒ stable particles/antiparticles produced in pairs
  - Annihilation and pair creation in early universe ↔ annihilation to γ-rays in present-day halos. Detection cross-section (annihilation to continuum γ-rays) is closely tied to the cross-section maintaining thermal equilibrium in early universe.
  - Accelerator constraints and cosmological constraints put the mass in the range of 10s of GeV to unitarity limit (~100 TeV), with likely range ~50 GeV to a TeV - well matched to ACTs

Key Points

- Where should we look?
  - Galactic substructure - follow-up observations of GLAST unidentified sources to measure angular distribution, cutoffs and lines
  - Survey of local group Dwarf Spheroidals - average over variance in halo profile due to baryonic matter, tidal disruptions
  - GC has large astrophysical backgrounds, but spectral cutoff and line signature could be seen by excluding the GC source and selecting an annulus about the GC (Stoehr et al., 2003)



High resolution simulation of structure formation showing earth-sized microhalos which might pervade local space, and give an observable signal (Diemand et al., Koushiappas)



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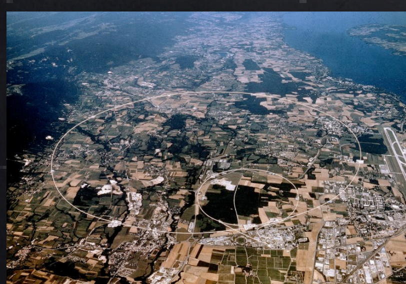
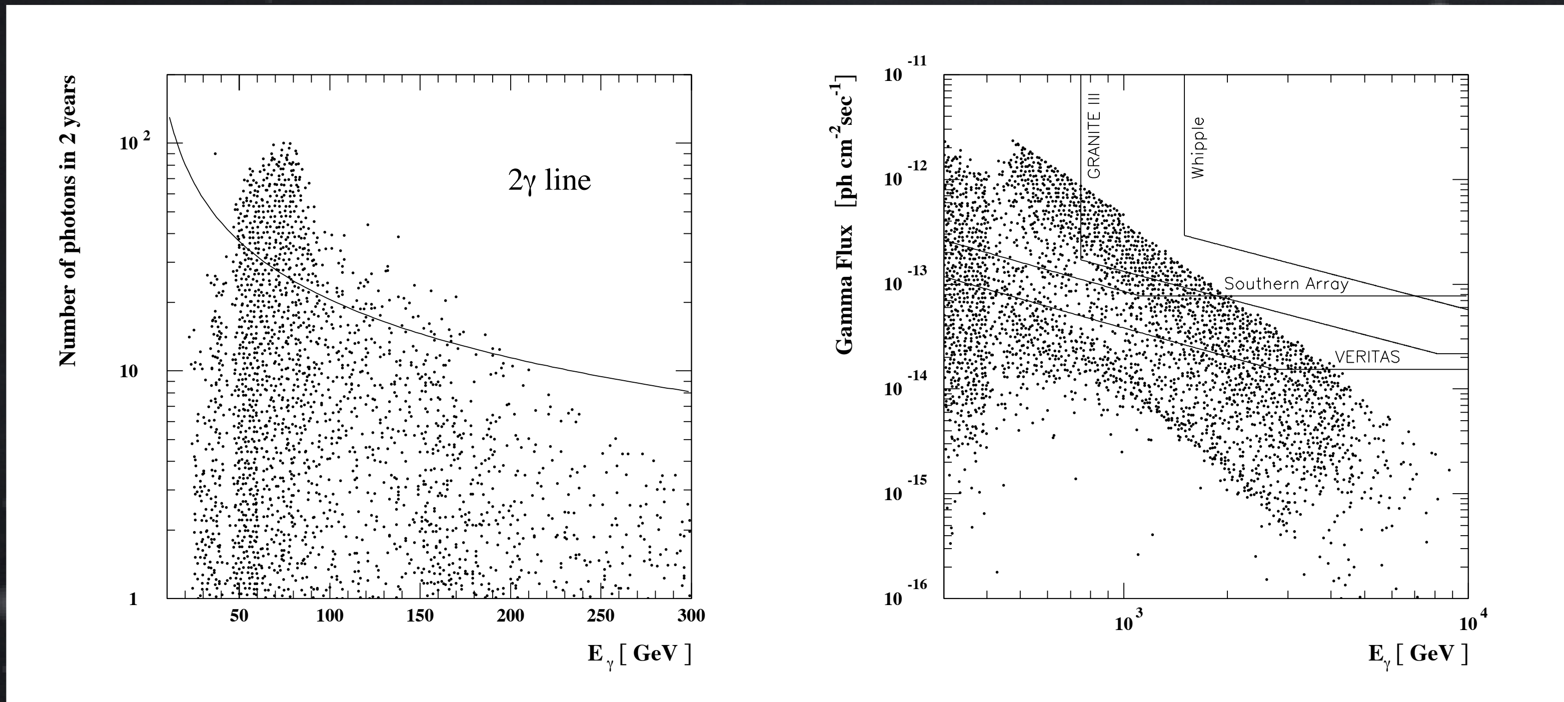


- Complementarity?
  - For energies < 200 GeV, GLAST most sensitive to continuum emission from γ-ray sources; >200 GeV instruments such as VERITAS and HESS provide the best sensitivity. However, for detection of an annihilation line or cutoff feature, ground-based instruments are probably the only means of detecting enough photons.
  - If a neutralino has a mass <500 GeV, the LHC could directly observe it. Above 500 GeV, direct detection experiments and indirect astrophysical experiments are needed.
  - While dark matter may be detected at the LHC or direct detection experiments, gamma-ray measurements provide the only possible means of observing the halo distribution and of verifying the role of such particles in structure formation of the universe.

Annihilation Lines



- Bergstrom et al. Astropart. Phys1998) found that for the GC, an ACT could potentially probe more parameter space with better sensitivity for detecting a gamma-ray line
- For the continuum emission, integrating down to the instrument threshold, GLAST can do better than VERITAS for masses up to a couple hundred GeV (e.g., Koushiappas 2006, Baltz 2006)

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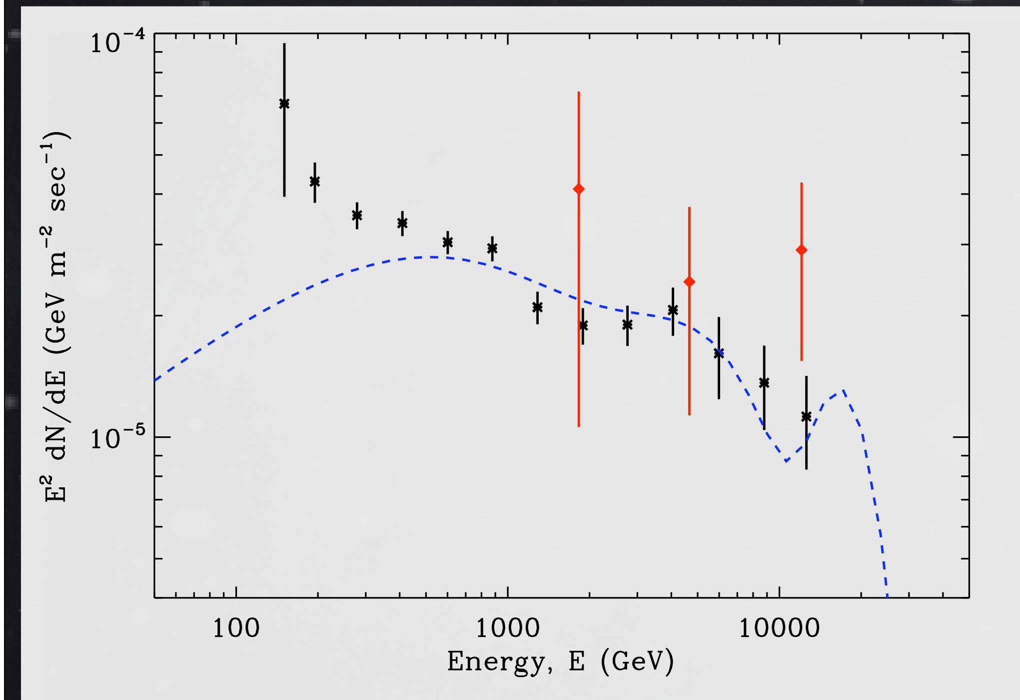

(Annihilation spectrum plotted over GC data points assuming 15 TeV mass, decay through t and τ channels, 25% energy resolution assuming line/continuum ratio of $5x10^{-4}$ following Fornengo, Pieri and Scopel, PRD, 70, 103529, 2004)

- Importance of Spectral Measurements
  - A universal cutoff and very hard spectrum would be strong evidence for dark matter
  - A GLAST detection would require more sensitive ACT measurements to define the shape of the cutoff.
  - ACTs have adequate resolution to resolve an annihilation line for some parameter space

Discussion Questions

- How important is wide field of view for Dark Matter searches?
- What energy threshold is required? Is 100 GeV low enough?
- Is even 10^{-14} erg cm^{-2} sec^{-1} good enough?
- Is Dark Matter a compelling enough reason to fund a \$100M experiment? How do we compare to a \$50M direct detection experiment?
- Are there new experimental (radio, IR, optical) data that could better constrain the halo profiles in the inner 100pc of galaxies?

Key Points

- Required Sensitivity

$$\rho(r) \propto \left[(r/r_s)(1+r/r_s)^2\right]^{-1}$$

Object	Mass (M_{sun})	Distance	Ang. Size (vir rad/dist) (deg)	Optimum SNR (arb. units)	Optimum Aperture (deg)	Signal relative to GC (pt src)	Sensitivity requirement (erg cm^{-2}s^{-1})
Minihalo	10^{-4}	0.5 pc	0.29	12	0.027	4×10^{-2}	2.3×10^{-13}
Dwarf Galaxy	10^{8}	75 kpc	0.15	5.8	0.020	1.1×10^{-2}	6.6×10^{-14}
GC	1.8×10^{11}	8.5 kpc	47	620	1.2	1.0	6.0×10^{-12}
Andromeda	1.8×10^{11}	730 kpc	0.48	5.6	0.034	2.7×10^{-2}	1.6×10^{-13}
Virgo Cluster	10^{14}	17 Mpc	0.39	1.5	0.034	0.6×10^{-2}	3.6×10^{-14}